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SOME RECENT DEVELOPMENTS IN FUEL TECHNOLOGY IN FRANCE

by

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CONTENTS

	Page
Introduction	1
Visits in the Paris Area	2
International Conference on Strata Control	2
Institut Français du Petrole	3
Gaz de France	4
Visits in South Western France	8
Parentis Oil Field	8
Lacq Gas Field	8
Lussagnet Gas Storage Field	12
Conclusion	13

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INTRODUCTION

One of the purposes of a field trip made in France in the Spring of 1960 by R.P. Charbonnier was to study the possibilities of application in Canada of some French equipment and techniques.

This report is a summary of contacts made and recent developments noted, firstly in the Paris area, at the International Conference on Strata Control*, at the Institut Francais du Petrole and at Gaz de France; secondly during visits in South Western France, at the Parentis oil field, at the Lacq gas field and at the Lussagnet gas storage field.

The most important developments noted have been the following: the mining methods in seams liable to rockbursts and bumps, the use of walking roof supports in coal mines, the statistical studies on convergence in mines, the "Lavodune" mineral classification equipment and the Neyrpic turbines for well drilling **, the I.F.P. studies on the flow of gases through porous media, the use of substitute fuels in Diesel engines, the underground storage of gas in aquifer formations at Beynes and Lussagnet, the storage and transportation of liquefied methane, the production of interchangeable gas substitutes to replace methane for peak shaving purposes, the very economical and efficient development and secondary recovery of the Parentis oil field, the great achievements in the Lacq gas field (e.g special corrosion-proof steels for sulfurous gas wells, tubingless completions, turbo-drilling for deep and difficult formations, improved gas desulphurization), the automatic remote controls of the Beynes and Lacq fields.

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* See "Report on the International Conference on Strata Control, Paris, May, 1960" by R.P. Charbonnier, Technical Memorandum IR-FMP-60/144-FRE, Mines Branch, Department of Mines and Technical Surveys, Ottawa, September 1960.

** Regarding the "Lavodune" and turbo-drilling, see the separate report on visits made at the Neyrpic plants in Grenoble and at the Coulommes oil field.

VISITS IN THE PARIS AREA

International Conference on Strata Control

During the International Conference on Strata Control a great number of contacts were established with many of the 500 registered members, mainly with officials of the "Centre d' Etudes et Recherches des Charbonnages de France" (Mr. Cheradame, Mr. Loison, Mr. Gatineau, Mr. Ducas, Mr. Ploix, etc.) and with engineers of the French Collieries, but also with some delegates from various countries (Britain, U.S.A., South Africa, etc.). In some specific aspects of mining, the Canadian mining industry could greatly benefit from the experience obtained in other countries in research techniques and equipment and also in production technology.

French coal mining may serve as an example of such achievements: coal production has been increased from a level of about 50 million tons before World War II to approximately 90 million tons of raw coal (before cleaning), average underground output/man/shift has been raised from about 1.2 tons to more than 2.5 tons of raw coal, which is the largest increase outside of North America.

This success was obtained in spite of mining conditions which are among the worst in the world. The main factors of progress were mechanization and changes in mining methods. There are still many marginal operations, but they are gradually replaced by such underground mines as Merlebach in Lorraine, which probably holds the production records outside of North America with 17,000 tons/day and 5 tons of coal/man/shift. Some of the interesting features of the French collieries are the mining methods used in seamsliable to rockbursts and bumps, the extensive use of diesel locomotives underground, walking roof supports, self-guided heads on continuous miners, cutter-loaders such as the "Valantin"

unit, coal cleaning control, "Lavodune" coal cleaning equipment, and briquetting equipment (1) and techniques (2).

Institut Français du Petrole

Visits were made to the Production Department of the "Institut Francais du Petrole". Discussions were held with several members of the Department, including Mr. Poupon (Director), Mr. Lebreton, Mr. Monicard, Mr. Munier-Jolain. The purpose of these interviews was to survey the general trends of new developments of French technology in petroleum reservoir engineering, production and secondary recovery methods, in preparation for the study of specific subjects, which was to follow. Contacts with the French Petroleum Institute (F.P.I.) are important for us and have contributed in the past very valuable reservoir engineering documentation and theories (such as Dr. Houpeurt's thesis and outstanding studies with R. Iffly on the flow of gases through porous media), and also interesting data on very specialized subjects such as the underground storage of gas in aquifers in which the F.P.I. has pioneered.

It was decided that the main specific subjects to be considered in ulterior visits would be as follows: underground storage of gas at "Gaz de France" and Lacq; methane liquefaction, transportation of liquefied methane, and replacement gases at Gaz de France; turbo-drilling and sour gas field operation at Lacq; turbo-drilling and "Lavodune" classification equipment at Neyrpic (Coulommes oil field and Grenoble plants).

A number of interesting documents on estimation of reserves, reservoir drainage and secondary recovery were obtained from the F.P.I. Some developments of techniques and equipments made by the French industry and the F.P.I. may be of

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(1) Charbonnier, R.P., and Rozenhart, C.F.J. "The Compressive Strength and Tumbler Tests as Criteria of The Physical Properties of Briquets". F.R.L. Report No. 249, Mines Branch, Department of Mines and Technical Surveys, Ottawa, 1956.

(2) Charbonnier, R.P., and Visman, J. "Briquetting coal with Binders and Statistical Evaluation of Briquet Tests". Technical Bulletin T.B. 9, Mines Branch, Department of Mines and Technical Surveys, Ottawa, October, 1959.

special interest for the Canadian industry where they might be advantageously adapted. For instance, substitute fuels have been successfully used in modified Diesel engines, e.g. Sahara crude oil instead of Diesel Fuel. Similar problems have arisen in the operation of the Canadian railways Diesel locomotives (3).

Gaz de France

Several visits were made to the offices and laboratories of "Gaz de France" in Paris. Discussions were held with Mr. Kec, Mr. Nivault, Mr. Verret, Mr. Brunelli, Mr. Charlier, Mr. Bresson, Mr. Richard, Mr. Fort, Mr. Salvadori, Mr. Lovy, Mrs. Vignes etc. The installations for underground storage of gas in an aquifer strata at Beynes were visited under Mr. Bresson's guidance.

They offer considerable interest for the Canadian natural gas industry, which is faced in Southeastern Ontario and in the Quebec Lowlands with problems similar to those solved by Gaz de France at Beynes, i.e. the necessity of providing large storage for gas in an area where there are no partly depleted fields (4).

Abundant data and documentation were obtained from Gaz de France on the experience gained in recent years in the selection and operation of the Beynes Storage field, which may serve as an example for the solution of the peak shaving problems in the Toronto-Montreal area.

The only other rare examples of application of similar techniques have been in Germany and in the U.S.A. but generally in more favourable conditions regarding the quantity of data initially available for the selection of a suitable structure. Beynes is the largest artificial storage reservoir in its class in the world. Maximum withdrawal is estimated at about 8 million (MM) cu. ft./hour, corresponding to a deliverability of approximately 160 MM cu. ft./day. The cokery gas presently in storage is in the order of 10 billion cu. ft. At capacity, the

(3) Charbonnier, R.P. "Possibilities of Utilization of Surplus Liquefied Petroleum Gas in Railway Locomotive Engines in Canada". Technical Memorandum IR-MMP-60/138-PRE, Mines Branch, Department of Mines and Technical Surveys, Ottawa, September, 1960.

(4) Charbonnier, R.P. "Present Status of Underground Storage of Natural Gas in Southern Ontario and Quebec". Information Circular IC 121, Mines Branch, Department of Mines and Technical Surveys, Ottawa, May, 1960.

cushion gas will be about half of the total volume stored. Injection rates have been in the neighbourhood of 40 MM cu. ft./d.

Maximum deliverability now exceeds one third of the maximum expected demand of the Paris area which Beynes serves. Normal pressure cycles are expected to fluctuate from 450 to 700 psi. The reservoir consists of a sand dome where porosity is about 30% and permeability 5 to 15 darcys, this high figure being the major factor permitting the relatively high deliverability. The depth of the reservoir is about 1,000 feet and the tightness is provided by a thin (about 25 feet) overlying strata of clay. The reservoir is operated by 14 wells for injections and withdrawals, 2 wells for gas bubble control and 7 wells for water and leak control. The wells are operated by remote control from a central station. A compression station operates between 250 and 700 psi. The nature of the gas requires a treatment before injection and dehydration after withdrawals. A typical Schlumberger log record was obtained from G.d.F. showing the microlog electric log, gamma-ray log and neutron log. Performance history curves were also received, which show interesting data on the fluctuations of pressures and volumes.

Valuable studies were also obtained from Gaz de France regarding comparisons of the economics of underground storage of gas and interruptible industrial demand and regarding the determination of the optimum of equipment of an underground reservoir with limited storage by means of operations research methods. The first topic is especially interesting in connection with the possibly excessive reliance on interruptible sales used for peak shaving in the Montreal area.

Visits were made at the "Centre d' Essais et de Recherches du Lendy" of the "Direction des Etudes et Techniques Nouvelles D.E.T.N." of Gaz de France.

Although some studies presently undertaken are still in a preliminary stage, it was of great interest to note the important program now initiated on the liquefaction of natural gas and the storage and transportation of liquefied methane. Various materials are tested as heat insulators, and special powders seem to give promising results. Transportation of liquefied methane by special

tankers seems to be regarded in France as the cheapest and most flexible means of building up substantial markets in Northwestern industrial Europe for natural gas produced in the French Sahara. After the gas demand has grown sufficiently, Sahara gas is to be transported in even larger quantities and more cheaply by a Trans Mediterranean pipeline through Spain or Italy. It seems that Gaz de France with Shell-Royal Dutch and other companies (such as Constock of Methane Pioneer fame) are actively engaged in the preliminary studies for this huge undertaking. The main incentives are: the large and increasing demand for cheap energy in North West Europe; the relatively short distance between the French Sahara and North West Europe (compared to the Middle East, North West Canada, Venezuela and the Gulf of Mexico gas fields); finally, the importance of the Hassi-ER'Mel gas field in the Sahara. This field is the second largest in the world with about 35 trillion cu. ft. of reserves compared to 70 trillion cu. ft. for the tri-state Hugoton (U.S.A.) field, which was developed between the two World Wars and is therefore well known. When the Hassi-ER'Mel field is developed, it may yield even larger reserves. The next three largest fields contain 14 and 12 trillion cu. ft. (in the U.S.A.) and 9 trillion cu. ft. (Lacq, in France).

It is often considered that there are good chances of finding large reservoirs of the Texas type in the Canadian North West Territories and it may well be that transportation of natural gas in a liquefied form would provide the only method of using such vast reserves. Storage of liquefied methane may also be considered for the solution of peak shaving problems in the Toronto-Montreal area. As the French industry seems to be taking the lead in these problems because of the higher incentives in the Sahara, it is likely that French techniques and equipment could eventually be profitably adapted to the Canadian requirements. It is still too early for significant developments, but good contacts have been established and mutual cooperation should be worthwhile for both Canadian and French industries. The present program already includes: a methane liquefaction centre

at Nantes near Brittany on the Atlantic coast, a detailed submarine survey of the sea depths and currents between Algeria and Spain, large scale tests of pipe laying at greater depths than has even been attempted and the preparation of an artificial underground storage reservoir for the natural gas in an aquifer at Vernon between Paris and the Atlantic ocean.

At the research laboratories of Landy, discussions were held on the feasibility of various techniques of production of gases which can replace natural gas for peak-shaving purposes. These techniques may have possibilities in the Montreal area and a number of documents were obtained regarding the studies, presently conducted by Gaz de France, on the interchangeability and production of such substitutes as: a mixture of propane or butane with air or gaseous combustion products, a mixture of gases obtained by auto-thermal reforming (P2 process) of propane enriched with untreated propane, or a mixture of gases produces by cracking and reforming (P9 process) of light distillates. The mixture air-propane has the advantage of lower cost installations and instantaneous operation but the P2 gas-propane mixture has the advantage of not introducing air in the pipelines. Products from light ends are not yet successfully interchangeable with natural gas, only with cokery gas.

Among the visits made in the Paris area, an interesting trip was made to the Coulommes oil field near Paris, where turbo-drilling has been extensively used. Discussions held in this connection will be reported later in the Section on turbo-drilling equipment made by Neyrpic at Grenoble.

Turbo drilling may be very useful for faster drilling with lighter tubing and rigs in the Canadian North West Territories where time and weight are very expensive.

VISITS IN SOUTH WESTERN FRANCE

Parentis Oil Field

Visits were made at the offices of the Esso Standard Oil Company, Bordeaux (Mr. Seguret, Mr. Lasalle, Mr. Huther, Mr. Delmas, Mr. L'Azou, etc.), where various reservoir engineering aspects of the Parentis oil field were discussed.

Parentis is one of the largest fields in Western Europe, the remaining reserves being estimated at about 140 million barrels. There are 29 present producers out of 37 wells drilled. Discovered in 1954, the field was completely developed in 1958, with a large part of the anticline drilled from platforms on the Biscarosse lake and also by deviated holes from the mainland. Average production per producer has been about 900 barrels/day. The total production is now limited to approximately 23,000 barrels/day and formation pressure is satisfactorily maintained by water injection (5 wells program - about 20,000 barrels/day of treated water). Esso-Rep has discovered in the same area four small fields which are under development: Mothes, Lugos, Lucats and Cazeaux. The Parentis oil field has characteristics very similar to those found in the Leduc Woodbend D3 pool in Alberta and it was very interesting to compare the solutions and results of secondary recovery operations in both cases. Under analogous circumstances, very similar results were obtained at Parentis with 29 wells as at Leduc with more than 500 wells. The tremendous wastes due to too close spacing in North America have recently been recognized but little is done to correct the very serious situation, and it may be imperative that the Federal Government should soon take action in this matter, where experience and techniques in other countries such as France may be useful.

Lacq Gas Field

Various interesting installations were visited in the Lacq gas field area. Discussions were held with a number of officials of the "Societe Nationale

des Petroles d'Aquitaine (SNPA)" (Mr. D'Haudeville, Mr. Rouchié, Mr. Vacher, Mr. Reverdy, Mr. Clarac, Mr. Destaillac, Mr. Chaloupy, Mr. Berger, etc.) and many valuable documents were obtained. The Lacq gas field has very peculiar characteristics. It is the fifth largest in the world with about 9 trillion cu. ft. of reserves. The reservoir is a dolomite-limestone-sandstone anticline of Jurassic and Neocomian Age at 11,000 ft. of depth (some wells reach 15,000 feet). The gas is at a temperature of 285°F and a bottom hole pressure of 9,670 psi and contains about 69% of methane, 15% of hydrogen sulphide, 10% of carbon dioxide and 5% of hydrocarbons with about 0.7% moisture. These factors combine to give most difficult conditions of exploitation, especially due to the extremely severe corrosive action of the gas on the pipes and other equipment (the tubing on the exploratory well in 1951 was destroyed in a few days). Special steels which may have some use in Canadian sour gas fields have been prepared and produced by the French industry and the drilling and operating technique is now fully satisfactory. Present output is in the region of 800 million cu. ft. per day from 30 wells.

Total production in 1959 was approximately: 85 billion cu. ft. of raw gas, which yielded 55 billion cu. ft. of clean gas, 415,000 tons of extra pure 99.95% sulphur and 116,000 tons of petroleum liquids, including 38,000 tons of LP Gas.

Total production in 1960 is estimated as follows: 160 billion cu. ft. of clean gas, 130,000 tons of propane and butane, 260,000 tons of condensates and 1.4 million tons of sulphur. Thus, Lacq has the largest sulphur extraction plant in the world and one of the largest natural gas processing plants.

It is particularly interesting to note the great progress made at Lacq in the development technique: even though special steels had been developed by the French industry to avoid the rapid corrosion due to atomic hydrogen produced by attack of the metal by the sulfurous gas, the slow corrosion and loss

of pipe thickness due to the reaction of the mixture of H_2S, CO_2 and water could be reduced only with inhibitors applied as films on the pipes. According to U.S. practice, the gas velocity had to be limited to 3 m/s to avoid the removal of the film. Conventional practice was the use of a tubing of 2-7/8 in. within a casing of 5 in. Production per well would then have been about 10 million cu. ft./day. With the usual techniques, the expected total output therefore required the drilling of 80 wells. Each deep well (over 11,000 feet through many difficult formations) required about 10 months to complete. To reduce the delays, turbo-drilling with both French and Russian turbines was tried. It was not found quite economical because of two main difficulties: well deviation and poor performance of drilling bits. However the competition created by the turbo-drills stimulated the rotary drilling techniques to adopt better procedures and auxiliary equipment, which resulted in the reduction of the average drilling time to 7 months and finally records of 4 months quite comparable to the best results obtained in the U.S. under similar conditions.

The order to reduce the number of wells required for the desired production, higher gas velocities were tried, but, as this was not sufficient, some tests were carried out with "tubeless" completions without a protection casing. As these tests proved very satisfactory it was decided that the ultimate field development would be as follows:

1 well with 2-3/8 in. tubing and 4 in. casing,
18 wells with 2-7/8 in. tubing and 5 in. casing,
9 wells with single telescopic tubing 3-1/2 and 4 in.,
5 wells with single tubing 4 in.

Eventually, ten of the wells with double tubing will be re-equipped with single tubing. Thus, for the same ultimate production of 800 million cu. ft./day, the number of required wells was reduced from 80 to 33 wells and completion of the field was achieved in 1960 instead of 1963.

Production per well for the best wells was increased from approximately 12 million cu. ft./day (with double tubing and 3 m/s gas velocity) to 40 million cu. ft./day (with single tubing of 4 in. and 11 m/s gas velocity).

Gas processing in the huge Lacq plant consists of three main operations: desulphurization, condensate recovery and sulphur recovery. In the first plant, sulphur removal is achieved by the classic method similar to the processes widely used in Alberta: the raw gas is washed at 1050 psi through a solution of diethanolamine, thus yielding sulphides and carbonates which are unstable at high temperatures. The cleaned gas is further treated in a solution of soda and the used solution of diethanolamine is heated at 140°C to release the sulfurous gases.

In order to reduce the quantities of steam required for regeneration of the ethanolamine, the SNPA has designed another process, which is successfully used in the newer plants at Lacq, and could be of interest for the Canadian industry: the raw gas is first washed in water at 1100 psi and the acid gases are recovered from the solution by expansion without heating. The washed raw gas thus obtained is less rich in acid products and can be treated in a process similar to that used in the first plant, but at a much lesser cost.

Condensate recovery was achieved by oil absorption under pressure in the first plant, with separation by distillation. In the second plant, a liquefaction and fractionated distillation process was adopted to increase the recoveries of propane and butane.

Sulphur recovery is obtained by partial oxidation of the H_2S by air in ovens and condensers. The catalyst used is an activated bauxite containing oxides of Al, Fe, Si and Ti. The free sulphur obtained is maintained about 150°C and poured on storage areas where it solidifies.

A large industrial complex using natural gas is under construction in the Lacq area. It includes mainly: a power plant of 3 or 4 units of 125 mega

watts each, which will chiefly supply the electricity for aluminum plants producing 73,000 tons of Aluminum per year and for chemical plants with a daily production of 75 tons of acetylene, 220 tons of ammonia, 100 tons of methanol, fertilizers, etc.

The largest gas pipeline network in Europe (outside of the USSR) has been built in two years. It reaches as far as Nantes, Paris, Jura (near Germany) and Lyon with about 1600 miles of 24 in. pipeline trunklines (pumping pressure about 1000 psi).

Lussagnet Gas Storage Field

The Lacq gas field and the gas processing plants must operate at a load factor as high as possible and it is also necessary to ensure the regularity of gas supplies to the pipelines. Therefore a large storage capacity for the processed gas was required close to Lacq. As no partly depleted gas fields were known in this area, the SNPA decided in 1957 to prepare an artificial gas reservoir in an aquifer strata at Lussagnet about 35 miles from Lacq. The sand reservoir covered by thick clayish limestones is over 130 feet thick; the summit of the elliptic dome is at a depth of about 1600 feet and the natural pressure of the aquifer is close to the pipeline pressure, so that the expenditures for recompression are relatively low. The reservoir porosity varies from 15% to 35% in the deeper levels; permeability varies widely from about 100 md to several tens of darcys. The reservoir sand is unconsolidated, therefore special completion methods are necessary. Beynes and Lussagnet are the only artificial gas reservoirs of this type in the world, the others are in firm formations. Gravel packing completions have given the best results.

Minimum working storage capacity is estimated at about 25 billions cu. ft. The distance between wells is about 450 feet. Maximum withdrawal is about 10 million cu. ft./day per well, and about 180 million cu. ft./day for the whole reservoir. Storage pressure is cycling between 61 and 65 kg/cm^2.

Total gas now in storage is in the order of 18 billion cu. ft. All together 32 wells(usual tubing 3-1/2 in., casing 7 in.)have been drilled including 10 exploration and observation wells for the control of the water level and other factors of the operation. Back pressure tests are extensively used. The average output corresponding to a well head pressure differential of 75 psi is estimated at about 8 billion cu. ft./day/well, but reaches 12 billion c.f./d for the best wells. Dewatering of the gas produced is obtained by the classic glycol process.

A special singularity of the Lussagnet field is the great irregularity of the operation which may have to be modified from 10 to 15 times every day to suit the wide fluctuations of the supply from Lacq and the pipeline network demand.

Very interesting data were obtained concerning the techniques used for the preparation of the Lussagnet field, as these methods may be useful for any aquifer storage project in the Montreal area.

A special mention must be made of the outstanding remote control installations for operating the wells both in the Lacq field and in the Beynes reservoir. For safety reasons (H_2S, populous area, lack of alternative facility for emergencies, etc.) these remote controls had to be extremely reliable and the French achievements in these two fields may be of interest for LACT installations in Canada.

CONCLUSION

The numerous and important technical developments described above are of great interest for the Canadian mining and petroleum industry. Although many conditions are different in the two countries, a number of these French techniques could be adapted for application in Canada. It is desirable to keep as well informed as possible of new developments in other countries especially the progressive industrial nations where the language barrier prevents easy exchanges of information with the predominantly English-speaking Canadian fuel industry.